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Sensitivity of Benthic Microflora to Pollution Gradients

W70-08164

Final Project Report on Grant 1WP-01220

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The objective of the Program

This program was initiated in June 1967 to evaluate relationships between the productive condition of the sediment environment and pollution effects normally experienced along a densely populated coastline. Specifically the work was designed to:

(a) improve the methodology for measuring the productivity of the benthic microflora community;

(b) determine the normal rate of productivity of the microflora community of shoal benthic environments, as indicated by the rate of ^{14}C uptake by intact samples of samples;

(c) compare this norm with productivity in an area affected by heavy domestic pollution and an area affected by thermal addition.

~~Results of the research program are presented in this report.~~ This terminal report indicates considerable accomplishment under "a" and "b", and this is becoming available in scientific publications.

As to "c" we can only report on a representative domestic pollution situation. Though the location selected for observations on thermal addition effects may, in the coming years, become one of the world's largest nuclear

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power plant sites, though the Millstone Point Company is pursuing a long range ecological monitoring program of the marine environment in that area and, though the effects on sediments studied under this grant were designed to supplement the Millstone Point Company effort, FWPCA has not continued to support this work.

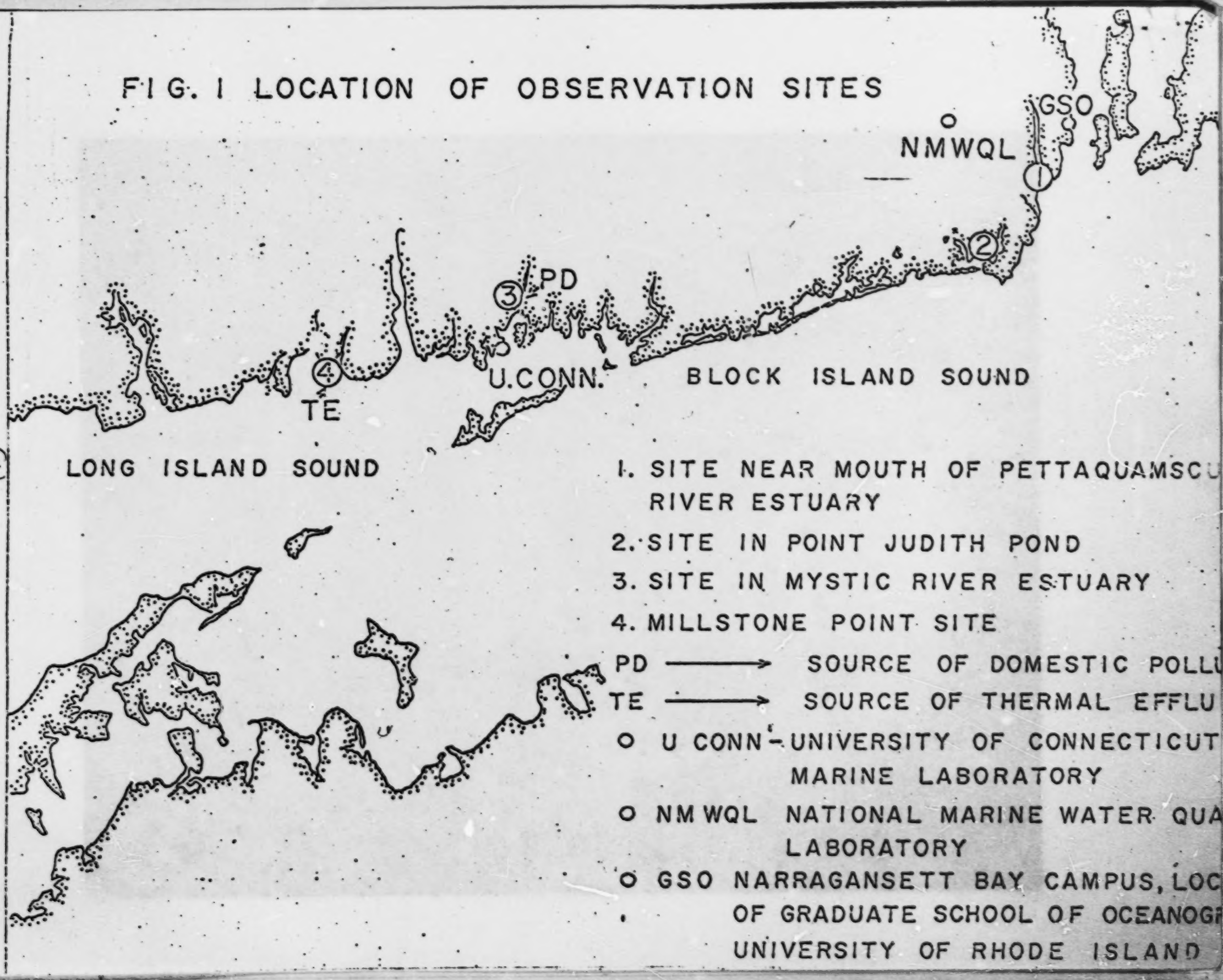
The Observation Stations

Some of the observations made date back to February 1966 and the full coverage of stations started in July of that same year. The stations selected for shoal benthic environment productivity observations are shown in Figure 1. Stations 1 and 2 have not been modified by apparent stress and will act as representative background stations helping us to establish the norms for productivity in such environements. Station 3 in the Mystic River is a site where there is a heavy load of domestic pollution. Station 4 is adjacent to the effluent of the Millstone Power Plant site and now stands as a station for which we have data on preoperational conditions, though, as just noted, we will not have the opportunity to compare the normal with the thermal effluent conditions expected as the first plant goes "on line" this coming summer.

The depth of the sampling area at all four stations was about 1/3 M at mean low water and the tidal range was about a meter. At all locations the bottom sediments were of mixed sand and mud so characteristic of the benthic environment just offshore from the sand and gravel laden intertidal areas. Stands of Zostera occur off the Point Judith estuary and Pettaquamscutt River sites but our stations were just shoreward of the eelgrass cover. In fact, except for the scattered Ulva developing in the Mystic River and Millstone Point sites in mid-summer, all sites were very free of macroscopic vegetation cover.

Figure 1. Location of Observation Sites.

FIG. 1 LOCATION OF OBSERVATION SITES



1. SITE NEAR MOUTH OF PETTAQUAMSCU RIVER ESTUARY
2. SITE IN POINT JUDITH POND
3. SITE IN MYSTIC RIVER ESTUARY
4. MILLSTONE POINT SITE

PD ⟶ SOURCE OF DOMESTIC POLLU

TE ⟶ SOURCE OF THERMAL EFFLU

O U CONN - UNIVERSITY OF CONNECTICUT MARINE LABORATORY

O NMWQL NATIONAL MARINE WATER QUA LABORATORY

O GSO NARRAGANSETT BAY CAMPUS, LOC OF GRADUATE SCHOOL OF OCEANOGR UNIVERSITY OF RHODE ISLAND

Since the sites selected were in protected estuaries, waves seldom exceeded 10 cm and there was no surge. Currents in these habitats were primarily tidal and were modified by winds. It is doubtful that the currents ever exceeded one quarter knot except for the somewhat more sweeping circulation around the point where the Point Judith Pond observations were made. The Millstone Point station, being semi-enclosed by a jetty, had very little current. The salinities are presented in Table 1 and water temperature and light records on Figure 2a - 5a and 2b - 5b.

During 1968 limited winter counts were made of the benthic microflora at the sampling stations seeking some initial suggestions as to indicator species and community differences. These preliminary attempts are shown in Table 2. In this table spp. indicates forms believed to belong to the genus noted but not differentiated as species; sp_1, sp_2, etc. indicates forms that are apparently separate species though not identified as yet.

METHODS

It has been emphasized throughout the study that one major objective was to develop suitable methodology for measuring the productivity of the benthic sediment environment. The many complications involved in this undertaking have been discussed in the original application and progress reports. Most observations on the productivity of benthic microflora, by other workers, have involved disrupting the sediment, thereby only obtaining a productivity response in an unnaturally dispersed state. The methodology we have developed, which includes working with the sediment samples intact, analyzing the results for variation by critical statistical methods, and checking possible sources of variation and confidence is described in Appendix, taken directly from a manuscript prepared for IBP/SCOR Working Group on "Estimation of Primary

Table 1. Salinities

Date		Salinities ‰ at the sampling sites						
		Pettaquamscutt Shoals at Middlebridge	Point Judith Pond		Mystic River Estuary		Millstone Point	
			Date		Date		Date	
June 1967	2	16.8						
	15	23.4						
	22	18.3						
July	11	22.2	18	27.6			31	29.0
	19	24.0						
Aug.	8	19.4	15	29.4	2	15.4	29	29.8
	17	25.8			30	13.8		
Sept.	15	30.7					30	28.3
Oct.			2	31.1	14	27.5		
Nov.	4	31.0	14	31.2	28	20.8		
Dec.	12	27.5	30	29.3				
Jan. 1968	27	28.9					13	30.0
Feb.			12	30.3			24	30.0
Mar.	14	9.2	28	29.4	22	4.9		
Apr.	25	30.4					10	27.5
May			12	29.1	5	28.8		
June	12	30.1	25	30.0	20	17.1		
July			6	31.1	29	27.2		
Aug.							20	29.7

Table 1. cont.

Salinities ‰ at the sampling sites

Date		Pettaquamscutt Shoals at Middlebridge	Point Judith		Mystic River Estuary		Hillstone Point	
			Date		Date		Date	
Sept.	6	31.2	21	31.6	4	30.5	5	30.4
Oct.	19	30.9			16	30.8	13	30.9
Nov.			2	32.0			16	30.6
Dec.	7	30.7	21	31.8	1	23.6		
Jan. 1969	19	31.3			12	9.4		
Feb.			1	31.7	2	27.1		
Mar.	1	28.2	15	30.9			29	26.7
Apr.					12	15.6		
May	3	30.4						
	4	18.7						
	18	19.0						
	30	30.8						
June			11	30.0			24	29.3
July	10	27.1	29	31.6	8	28.7		
	23	26.2						
Aug.	28	30.0	5	30.3	25	27.3	8	28.0
Sept.			10	30.0			24	30.3
Oct.	25	31.6	22	31.6	8	27.3		
Nov.	26	26.4						
Dec.			10	31.1			20	29.2

Table 2

Organism	Pettaquamscutt River 3/14/68	Point Judith Pond 2/12/68	Mystic River 2/8/68	Millstone Point 2/24/68
	Numbers per gram of sediment			
Achnanthes spp.	143,925	25,250		26,833
Achnanthes sp_1		25,500*	4,600*	10,500
Achnanthes sp_2			3,400	
Amphipleura spp.	3,271			
Anomoeoneis spp.	35,327	47,250	7,000	147,000
Asterionella spp.	5,233	29,750		5,833
Biddulphia spp.		1,000		
Cocconeis spp.	15,700	61,250*	4,800*	10,500
Cocconeis sp_1		7,750	800	3,500
Coscinodiscus spp.	5,233	8,250*		9,333
Coscinodiscus sp_1		9,000		
Cyclotella spp.		26,750*		
Cymbella spp.	654	5,250	200	21,000
Dimerogramma sp_1		6,750		3,500
Diploneis spp.	2,616	3,500		
Diploneis sp_1			1,000	
Diploneis sp_2				24,500
Eunotia spp.		2,000		3,500
Fragilaria sp_1		14,000	1,200	12,833
Fragilaria sp_2	32,056	80,250		58,333
Fragilaria spp.	72,616	115,250*	6,200*	88,666
Grammatophora sp_1	11,121	4,250	3,200	8,166
Mastogloia sp_1	20,934	11,750	3,000	
Mastogloia sp_2	3,925	6,250	1,200	12,833
Mastogloia sp_3			1,200	
Mastogloia sp_4	18,971	8,750		15,166
Mastogloia spp.				14,000
Melosira sp_1 & 2	78,504	20,250	19,400	43,166
Melosira sp_3			4,200	
Navicula spp.	10,467	18,500		60,666
Navicula sp_1			4,400	
Nitzschia spp.	17,663	57,500	11,800	63,000
Nitzschia sp_1	5,233		2,400	79,333
Nitzschia sp_2		26,750	2,800	5,833
Opephora ?	1,308			
Pinnularia spp.	5,887	30,500	13,200	35,000
Pleurosigma spp.	1,962	2,500	1,000	10,500
Podosira spp.		5,250	17,000	2,333
Rhizosolenia spp.		11,750		52,500
Rhizosolenia sp_1	8,504			
Stauroneis spp.	23,551	21,500	1,200	61,833
Triceratium spp.			600	3,500
Other forms	73,271	12,500	3,600	23,333

Detritus and bacteria were present in abundance in all samples; no quantitative data are presented. Also, no data are presented on dinoflagellates, filamentous algae or the presence of spores, pollen and possible fungi noted in some samples.

*Refers to minimal counts in samples in which it was quite obvious that many more specimens were present on sand grains.

Production Under Special Conditions" which requested such materials for a special publication on methods.

Observations on the Production of the Benthic Microflora as Indicated by

14C Uptake

Figures 2a - 5a present observed 14C uptake of four shallow water sites as determined by the Cab-O-Sil procedure during 1969 (see Appendix). Figures 2b - 5b present data from the two previous years when a wet oxidation procedure (also described in the Appendix) was used to separate labelled carbon from the sediment mass in order to proceed with the radioactivity determination. Data obtained by the Cab-O-Sil method and the wet oxidation procedure are almost comparable as shown in the Appendix.

In 1969 at the Middlebridge shoals of the Pettaquamscutt and Pt. Judith sites a high productivity peak was recorded in late spring - early summer before temperatures or light reached their summer maximums. Neither the Mystic site data nor the Millstone site data indicated these peaks. The Mystic site data indicated a very low productivity during the cold months and a constant but higher productivity during the warm months. The Millstone site data followed a similar pattern except for a small peak during September.

Data from 1968 differs somewhat. Middlebridge data at the shoals of Pettaquamscutt River was similar to previous years data except that there appears to have been more persistant high productivity during the summer of 1968. Pt. Judith data did not contain any summer peaks of productivity as was recorded for 1969, whereas Mystic River did have peaks of summer productivity in previous years but not in 1969. Millstone Point data for previous years appears very similar to the 1969 data. In fact, peaks of productivity may well have occurred at Mystic and Millstone during 1969 and have been missed by our sampling program since these peaks flare up and disappear within a relativly short period of time. As noted, peaks of productivity were not recorded at Pt. Judith but did occur at Mystic in previous years.

Figure 2a. Light energy, temperature and productivity at Middlebridge.

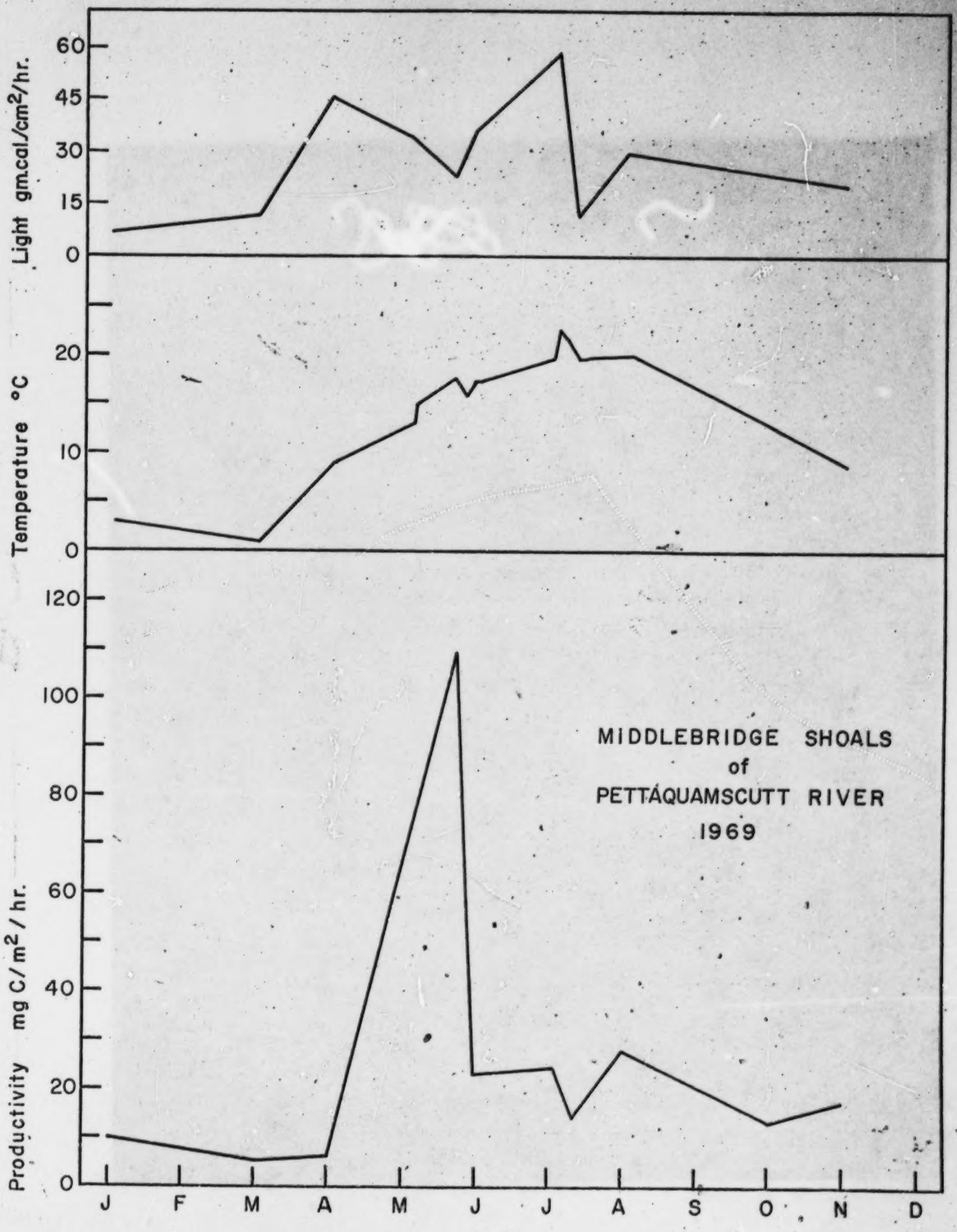
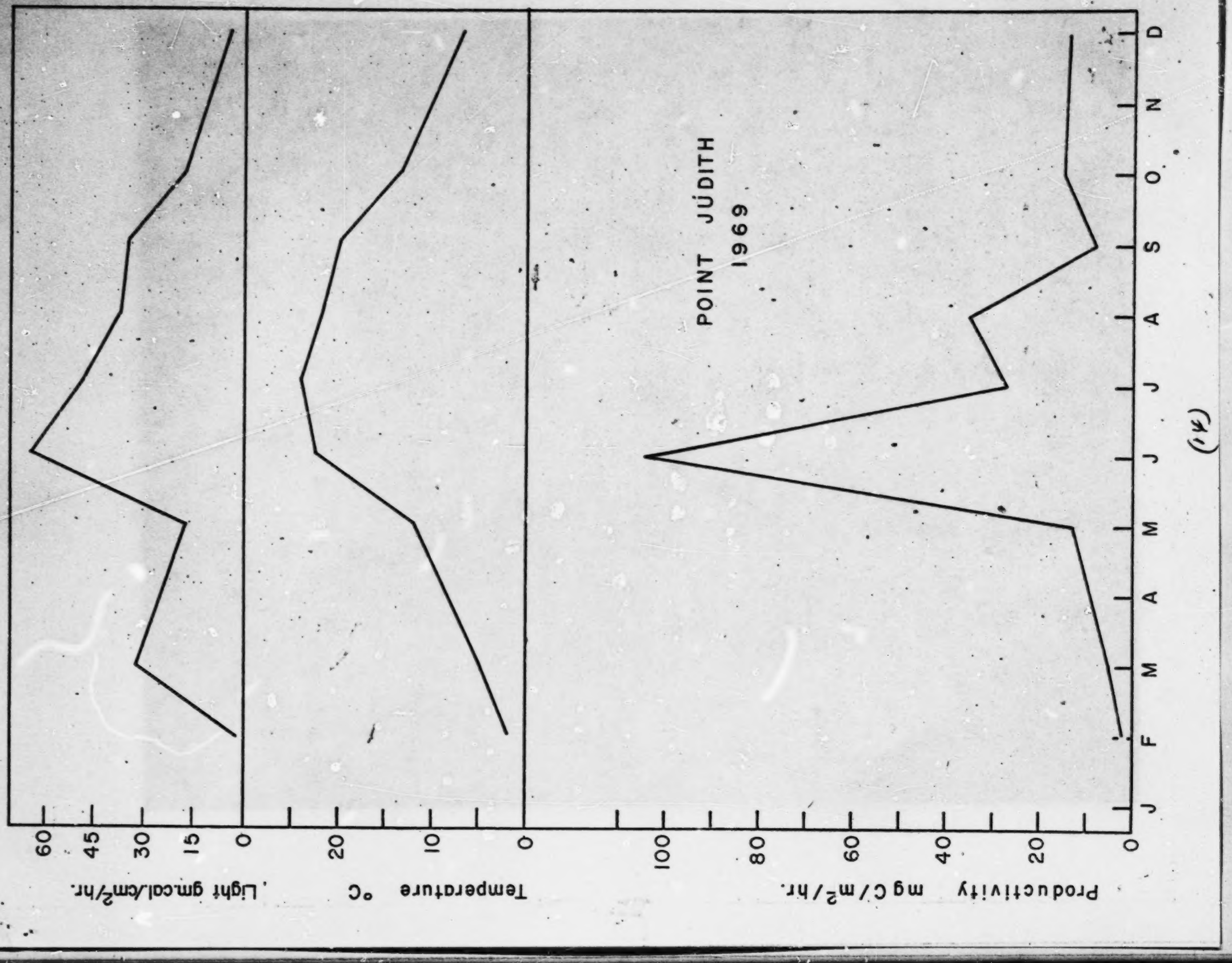

Light gm.cal./cm²/hr.
60
45
30
15
0
Temperature °C
20
10
0
Productivity mg C/m²/hr.
120
100
80
60
40
20
0
J
F
M
A
M
J
J
A
S
O
N
D
MIDDLEBRIDGE SHOALS
of
PETTÁQUAMSCUTT RIVER
1969

Figure 3a. Light energy, temperature and productivity at Point Judith.

POINT JUDITH

1969



(14)

Figure 4a. Light energy, temperature and productivity at Mystic River.

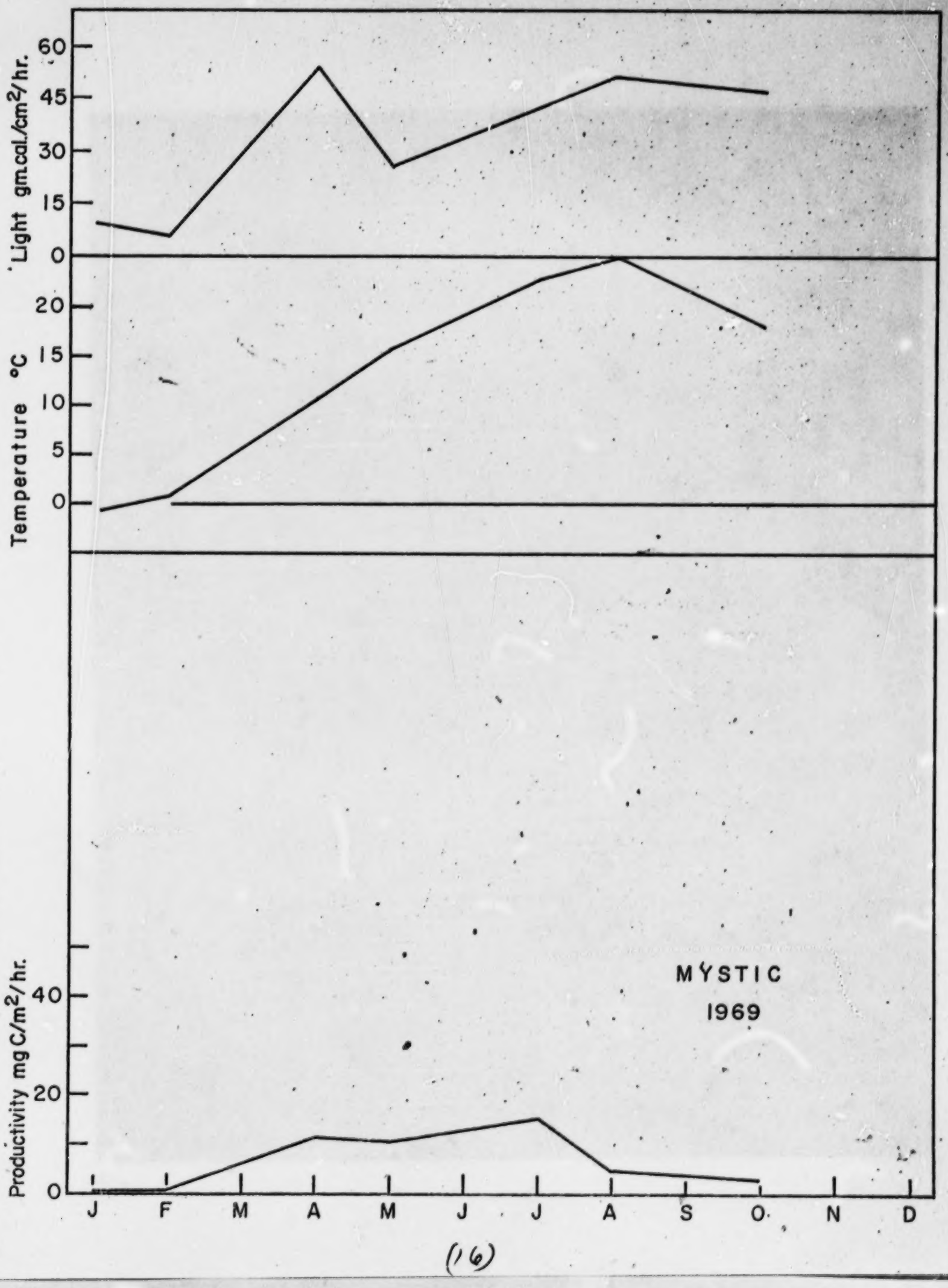

Light gm.cal./cm²/hr.
60
45
30
15
0
Temperature °C
20
15
10
5
0
Productivity mg C/m²/hr.
40
20
0
J
F
M
A
M
J
J
A
S
O
N
D
MYSTIC
1969

Figure 5a. Light energy, temperature and productivity at Millstone Point.

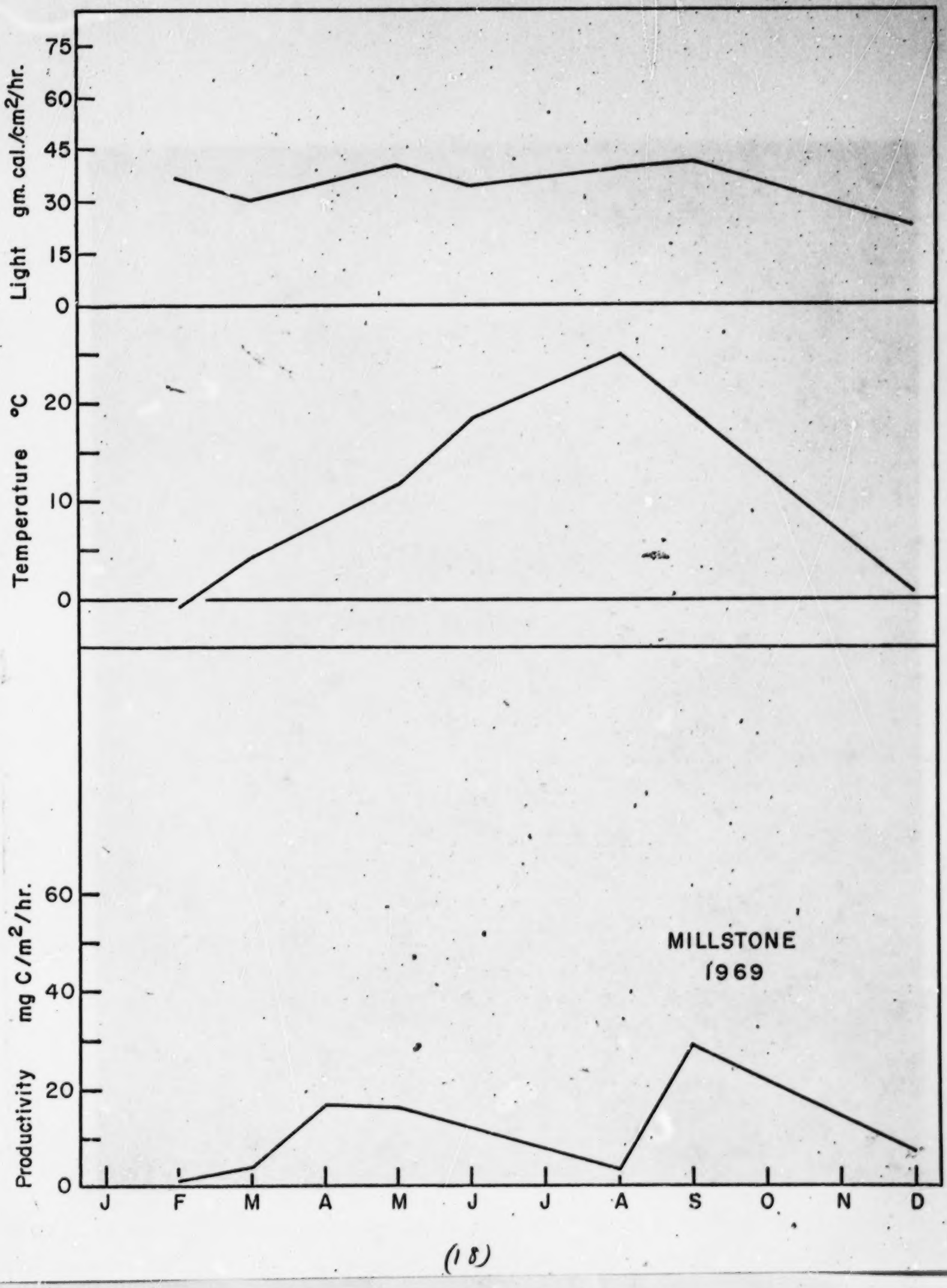
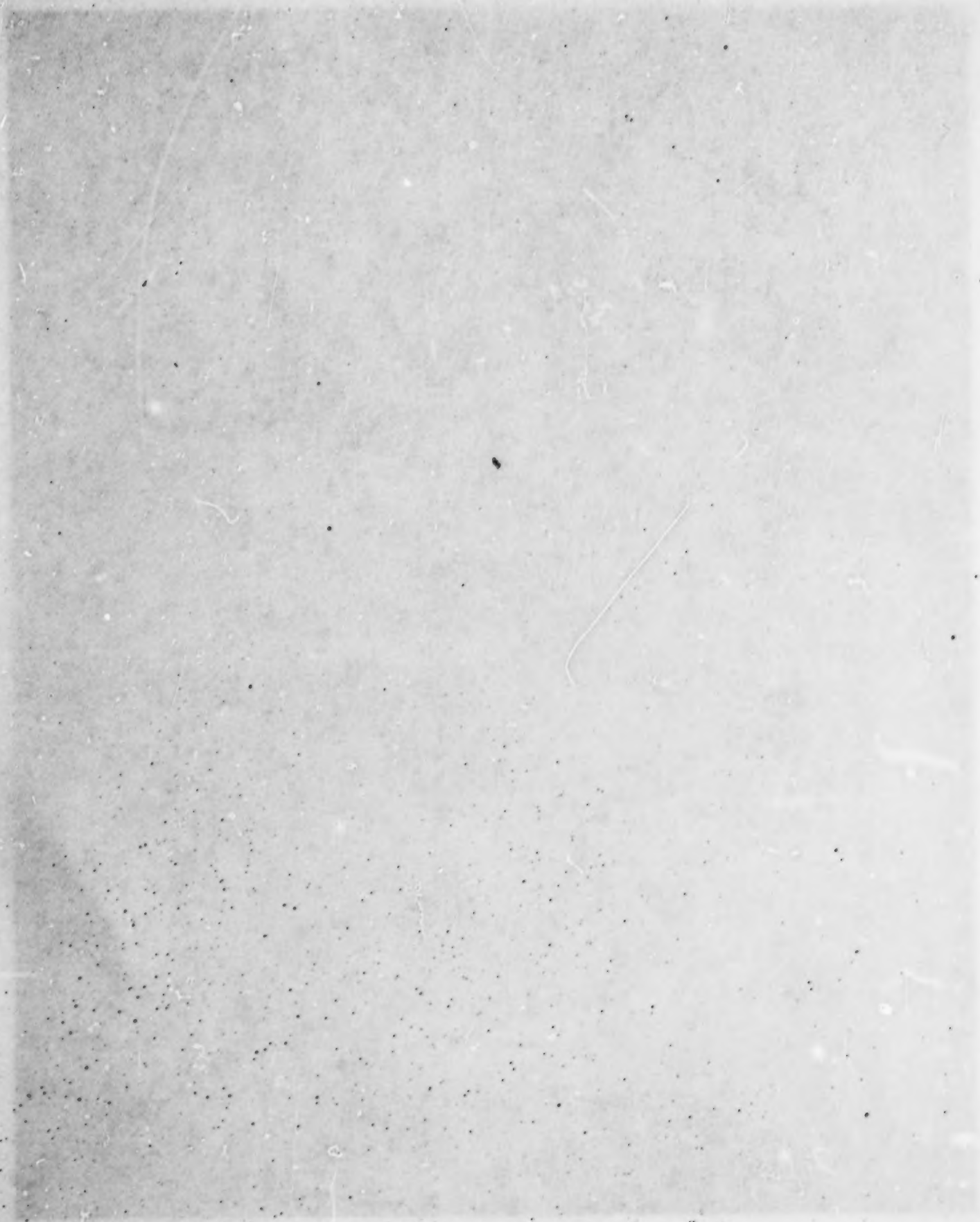

Light gm. cal./cm²/hr.
75
60
45
30
15
0
Temperature °C
20
10
0
Productivity mg C/m²/hr.
60
40
20
0
J
F
M
A
M
J
J
A
S
O
N
D
MILLSTONE
1969

Figure 2b. Light energy, temperature and productivity at Middlebridge.



Light gm.cal./cm²/hr.

60
48
36
24
12
0

Temperature °C

26
18
10
-2

°C

Productivity gC/m²/hr. (02)

140
120
100
80
60
40
20
0

158.1

Shoals of Pettaquamscutt River

1967 Feb. Mar. Apr. May Jun. Jul. Aug. Sep. Oct. Nov. Dec. 1968 Jan. Feb. Mar. Apr. May Jun. Jul. Aug. Sep. Oct. Nov. Dec.

Figure 3b. Light energy, temperature and productivity at Point Judith.

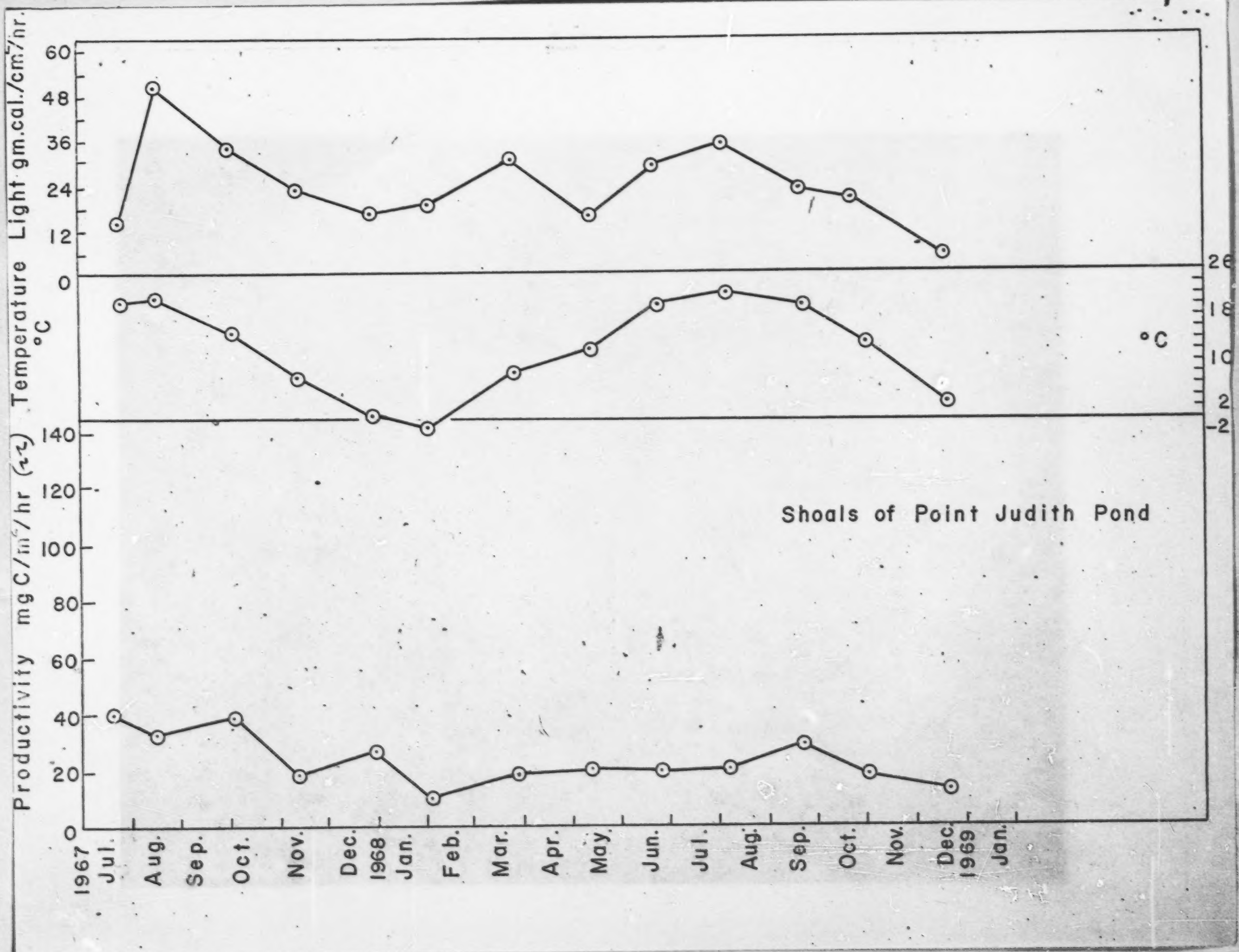

Productivity mgC/m²/hr (-12)
140
120
100
80
60
40
20
0
Temperature °C
Light gm.cal./cm²/hr.
60
48
36
24
12
0
°C
26
18
10
2
-2
Shoals of Point Judith Pond
1967
Jul.
Aug.
Sep.
Oct.
Nov.
Dec.
1968
Jan.
Feb.
Mar.
Apr.
May.
Jun.
Jul.
Aug.
Sep.
Oct.
Nov.
Dec.
1969
Jan.

Figure 4b. Light energy, temperature and productivity at Mystic River.

Shoals of Mystic River

Productivity mgC/m²/hr (ネ)
Light gm.cal./cm²/hr.
Temperature °C
°C
1967 Jul. Aug. Sep. Oct. Nov. Dec. 1968 Jan. Feb. Mar. Apr. May. Jun. Jul. Aug. Sep. Oct. Nov. Dec. 1969 Jan.

Figure 5b. Light energy, temperature and productivity at Millstone Point.

As discussed in detail in the Appendix variability in the sediment samples require a test for variance before comparisons between seasons and stations can be made. Standard deviations have been calculated as described in the Appendix.

For all four sites such statistical tests show significant differences associated with seasons, the productivity being least during the winter and greatest in summer (Tables 3 and 4). When stations are compared in terms of monthly sets of data (Table 3) statistical differences occur but these fail to show consistent patterns. In 1969 Middlebridge had a higher productivity than the other three stations; in March Mystic had a barely significant higher productivity than the other three stations; in May Middlebridge was again higher than the other three; in October Mystic was lower than the other three. In 1968 during March Pt. Judith was significantly higher than all stations and Millstone was significantly higher than Mystic and Middlebridge; during June Mystic was significantly higher than all stations; during September Pt. Judith was significantly higher than all stations and Middlebridge was significantly higher than Mystic and Millstone; during November Mystic and Millstone were significantly lower than the other two stations.

Middlebridge and Pt. Judith appear to be most productive sites, followed in order by Mystic and Millstone; however more sampling particularly at more frequent intervals in order to cover short peaks and other fluctuations are needed for adequate station comparisons.

Figure 6 and Figure 7 present suggested relationships between productivity and temperature and productivity and light for data collected in 1969. During 1968 productivity was measured on six occasions by the wet oxidation procedure with three different light exposures: full exposure at the sediment surface, light reduced by one screen, light reduced by two screens (Figure 8). On four dates

Table 3

(b) 1968 Processed by wet oxidation. Variance for data in blocked area was estimated on the basis of the average of 3 standards run with the individual samples; variance for data in unblocked area was estimated on the basis of the average of all standards processed by each 14C batch.

Date	Mystic			Middlebridge			Pt. Judith			Millstone			
1/68				17.15	24	3.70							
2/68	1.05	16	0.33				10.89	24	3.17	12.27	24	5.27	*
3/68	3.88	24	1.45	3.36	24	0.74	19.74	24	4.70 *	⇓			
4/68				14.82	24	2.92							
5/68	23.33	18	35.20				18.82	24	9.72	12.77	78	4.65	
6/68	84.56	24	49.16 *	20.02	18	6.34	20.02	15	6.81	⇓			
7/68										19.48	20	12.27	
8/68							47.65	24	24.45	22.51	20	10.16	
9/68	5.94	24	7.84	20.11	24	4.00 *	31.59	18	21.74 *	9.06	24	3.25	
10/68	8.93	24	3.23	14.06	24	8.35				7.42	20	3.55	
11/68							18.82	24	18.49	2.00	24	3.03	
12/68	-.16	24	1.26 *	12.90	24	3.48	13.91	24	22.17	5.39	16	0.97	*

n = sample size

s = sample standard diviation

⇓ indicates that data was used to complete a data set in a month adjacent to the month it was collected.

* indicates the difference between this sample mean and the other sample means is significant at the .01 level of confidence for the date indicated.

Table 3. A comparison of the average production as determined by 14C uptake at and between four stations by season during 1968 and 1969

(a) 1969 Processed by Cab-O-Sil

Date	Mystic	n	s	Middlebridge	n	s	Pt. Judith	n	s	Millstone	n	s
1/69	.003	20	.003	9.995	24	4.689						
2/69	1.382	20	2.235	*			1.860	24	4.458	1.183	20	1.255
3/69	*			5.352	24	6.935	5.128	24	6.203	4.099	16	8.066
4/69	11.544	24	8.523									
5/69	10.538	24	9.226	*66.716	12	34.823	12.552	24	30.442	16.528	16	36.500
				109.335	24	22.520						
6/69				23.017	24	6.084	104.200	24	108.467	16.439	24	18.236
7/69	15.479	20	13.832	23.539	24	17.276	26.764	16	11.661			
8/69	4.873	24	4.382	31.369	24	11.108	35.565	20	37.784	3.475	24	8.329
9/69							7.688	24	7.181	28.754	24	29.115
10/69	* 3.079	24	2.687	12.842	24	21.381	14.669	24	22.966			
11/69				16.734	24	31.406						
12/69							13.549	24	6.925	7.288	20	7.049

Table 4. Seasonal differences in microbenthic productivity as measured by 14C uptake at the .01 level of confidence.

	A 1969	B 1968
Mystic	1/69 < 4/69,5/69,7/69,8/69,10/69	2/68 < 8/68,6/68
	2/69 < 4/69,5/69,7/69,8/69	3/68 < 5/68,6/68
	4/69 < 7/69	5/68 < 6/68
	5/69 < 7/69	6/68 < ——
	8/69 < 4/69,5/69,7/69	9/68 < 5/68,6/68
	10/69 < 4/69,5/69,7/69	10/68 < 5/68,6/68
		12/68 < 5/68,6/68
Middlebridge shoals of the Pettaquamscutt	1/69 < 5/69,6/69,7/69,8/69,11/69	
	3/69 < 5/69,6/69,7/69,8/69,10/69,11/69	1/68 <——
	5/69 ① < 5/69 ② <——	3/68 < 1/68,4/68,6/68,9/68,10/68,12/68
	6/69 < 5/69,8/69	4/68 <——
	7/69 < 5/69,8/69	6/68 <——
	8/69 < 5/69	9/68 <——
	10/69 < 5/69,6/69,7/69,8/69	10/68 <——
	11/69 < 5/69,7/69,8/69	12/68 <——
Pt. Judith	2/69 < 6/69,7/69,8/69	2/68 < 3/68,5/68,6/68,8/68,9/68,11/68
	3/69 < 6/69,7/69,8/69	3/68 < 8/68,9/68
	5/69 < 6/69,8/69	5/58 < 8/68,9/68
	6/69 <——	6/68 < 8/68,9/68
	7/69 < 6/69	8/68 <——
	8/69 < 6/69	9/68 < 8/68
	9/69 < 6/69,7/69,8/69	11/68 < 8/68,9/68
	10/69 < 6/69,8/69	12/68 < 6/68,8/68,9/68
	12/69 < 6/69,8/69	

Table 4. cont.

A 1969		B 1968	
Millstone	1/69 < 5/69,6/69,9/69		2/68 < 7/68,8/68
	2/69 < 5/69,6/69,9/69		5/68 < 7/68,8/68
	5/69 < 9/69		7/68 < 8/68
	6/69 < 9/69		8/68 ←
	8/69 < 5/69,6/69,9/69		9/68 < 2/68,5/68,7/68,8/68
	9/69 ←		10/68 < 2/68,5/68,7/68,8/68
	12/69 < 5/69,7/69,9/69		11/68 < 2/68,5/68,7/68,8/68,9/68,10/68
			12/68 < 2/68,5/68,7/68,8/68,9/68

< : less than at the .01 level of confidence.

Figure 6. 1969: Temperature and 14C Benthic Microflora Production.

TEMPERATURE and 14C BENTHIC MICROFLORA PRODUCTION

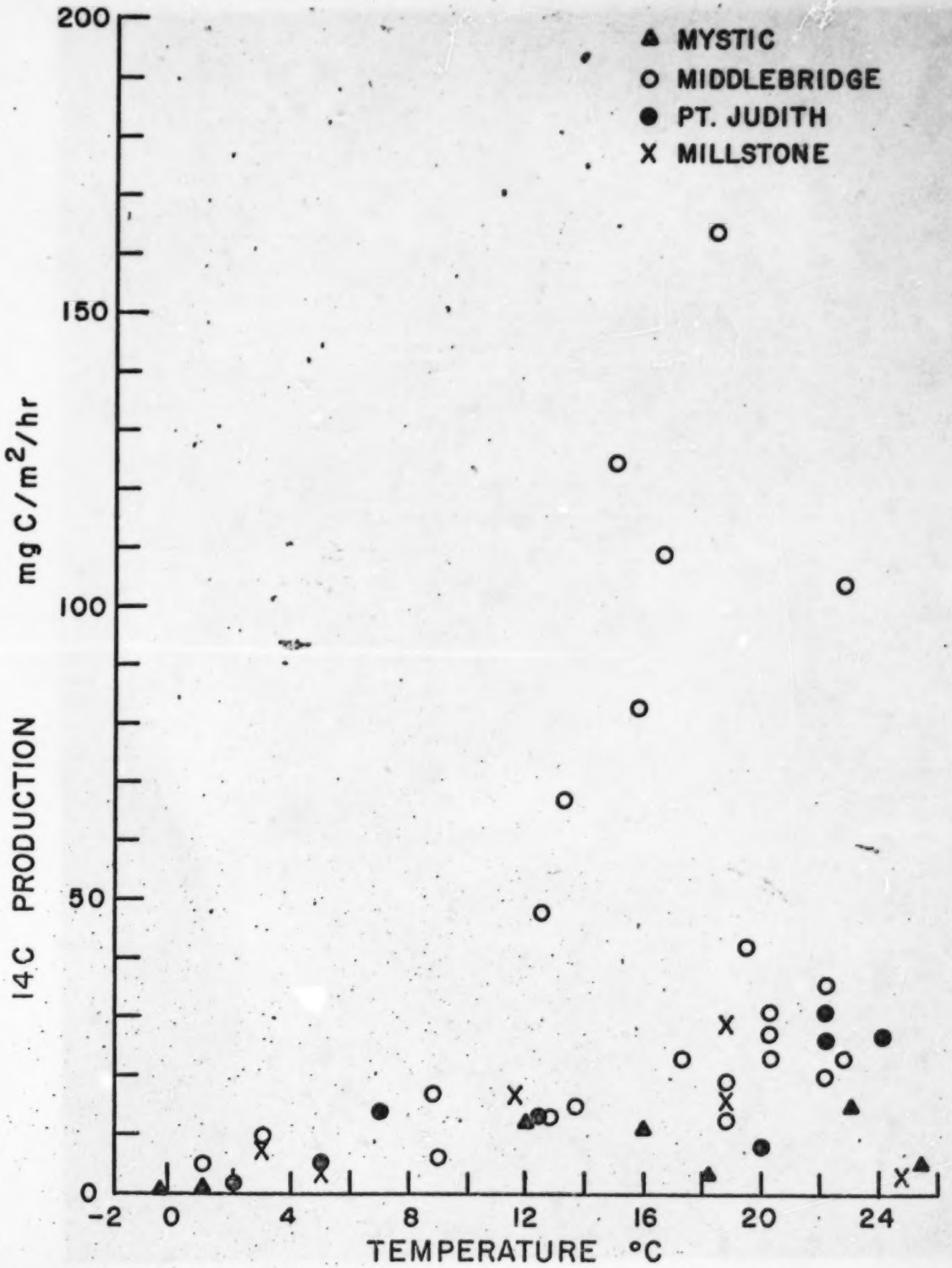


Figure 7. 1969: Light and 14C Benthic Microflora Production.

LIGHT and 14C BENTHIC MICROFLORA PRODUCTION

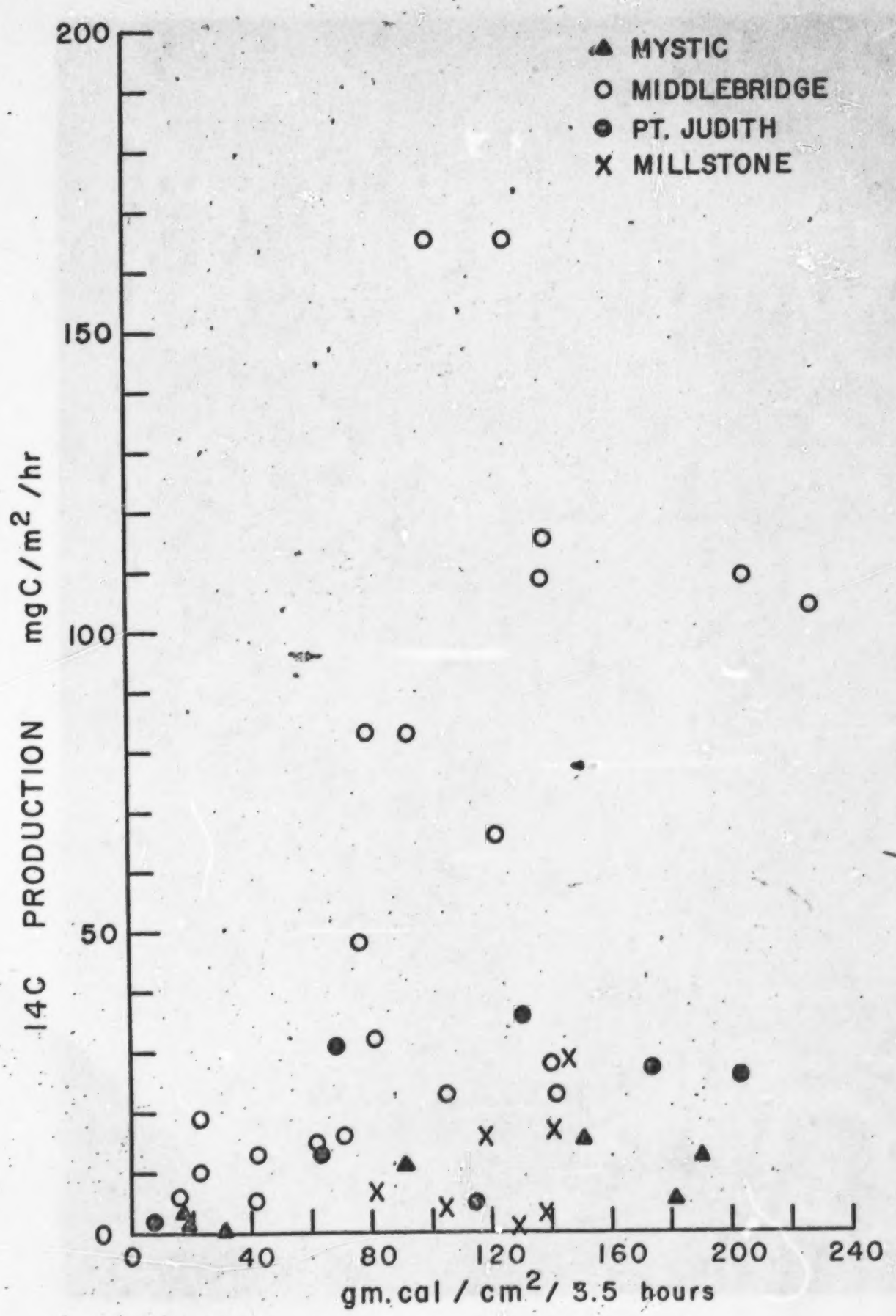
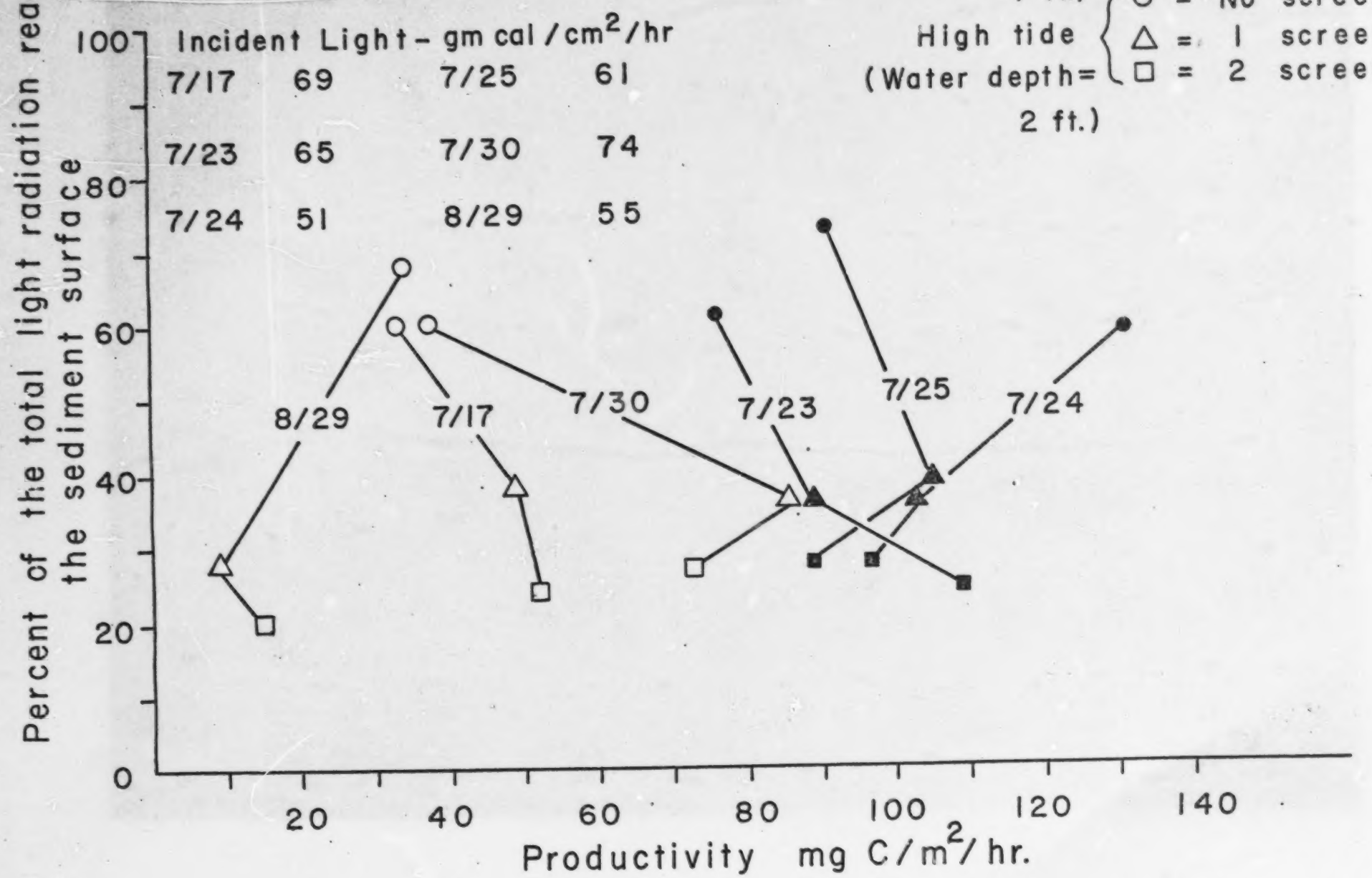


Figure 8. 1968: Light and 14C Benthic Microflora Production at different tidal stages.

Low tide (Water depth= 1 ft.)
- ● = No screens
- ▲ = 1 screen
- ■ = 2 screens

High tide (Water depth= 2 ft.)
- ○ = No screens
- △ = 1 screen
- □ = 2 screens



the productivity was greater when the light was reduced and, for the two dates when this did not apply, the incident of light was somewhat reduced. These data suggest that the strongest mid-summer light peaks may be in excess of the optimum for photosynthesis. In addition productivity at high tide was always less than at low, also suggesting reduced photosynthesis for high light intensities though the effect may be related to an upward migration of diatoms to the surface of the sediments at low tide.

Additional experiments, as shown in Table 5, seeking to correlate light and productivity were not successful. In part a of Table 5 mean values from triplicate experiments performed at depths differing by 0.3M did not show a correlation with light energy. These mean values were tested at the .05 level of confidence and this test did not indicate significant differences between any of the means. In part b mean values from triplicate experiments performed in the morning, mid-day and afternoon of the same day did not show a correlation with light energy. Two mean values tested significantly different at the .05 level of confidence on the afternoons of May 4 and May 18, 1969, however the highest light values on these days occurred during the mid-day experiments.

Table 5. The results for the influence of light on 14C uptake is presented for two sets of experiments:

(a) A comparison of 14C uptake at different depths at two stations.

Middlebridge	7/23/69				8/28/69			
	$MgC/M^2/hr$	n	s	light gm $cal/cm^2/3\frac{1}{2}hr$.	$mgC/M^2/hr$	n	s	light gm $cal/cm^2/3\frac{1}{2}hr$
Shallow	13.422	24	24.059	42.3	23.338	24	22.600	105.
Mid depth	12.961	24	15.105	41.7	31.369	24	11.108	82.4
Deep	18.753	24	24.921	23.3	27.656	24	18.372	140.

Pt. Judith	8/5/69			
	$MgC/M^2/hr$	n	s	light gm $cal/cm^2/3\frac{1}{2}$
Shallow	26.473	24	20.100	203.
Mid depth	35.565	20	37.784	131.
Deep	31.293	18	14.943	69.

Table 5 cont.

(b) A comparison of 14C uptake at different times of the day.

Middlebridge		$MgC/M^2/hr$	n	s	light $gm\ cal/cm^2/3\frac{1}{2}$ hr.
5/4/69					
Morning		48.375	24	48.919	145.000
Noon		66.716	12	34.823	225.000
Afternoon	*	115.230	20	86.892	193.000
5/18/69					
Morning		82.866	24	29.605	186.000
Noon		109.335	24	22.520	227.000
Afternoon	*	164.914	16	86.285	196.000
7/10/69					
Morning		41.764	20	63.772	154.000
Noon		23.539	24	17.276	291.000
Afternoon		29.900	24	20.069	151.000

n = sample size

s = sample standard deviation

* significant difference at .05 level of confidence

Use of Data

As pointed out in the Introduction, the research was terminated before all of the original objectives could be reached; nevertheless, the data obtained are extremely useful in our analyses of trophic relationships in shoal benthic environments. We have already been using these data in manuscripts on the benthic community and have been applying the method to get comparable data from marsh habitats. We will be publishing additional papers in which this information will be used. This contribution of the Federal Water Pollution Control Administration to basic research is greatly appreciated.

REFERENCES

Natrella, Mary G. 1963. Experimental Statistics, National Bureau of Standards Handbook 91, U. S. Gov. Print. Off., Washington 25, D. C. 23 Chapters.

Appendix

Measurement of primary productivity of intact samples of the benthic microflora.

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SUMMARY

Replicate cores from the top 3/4 cm of the sediment are kept intact and placed in separate light and dark flasks containing ^{14}C in filtered water from over the sampling site. The flasks are exposed to natural light for 3 1/2 hours, being positioned at the surface of the sediment where the cores had been taken. The cores are then transferred to glass fiber filters and washed to remove unbound ^{14}C. Each sample is pulverized, suspended in Cab-O-Sil® gel and counted by liquid scintillation spectrometry. Data are presented on the reliability and variability of calculations of primary productivity ~~obtained by this method.~~

ACKNOWLEDGEMENTS

Assistants at both the University of Connecticut and the University of Rhode Island who have actively participated during the years in which we have been evolving this method include: Roberta L. Davis, David M. Detweiler, Jack A. Donnan, Wayne F. Ferguson, Robert J. Fragala, Arthur G. Gaines, Donald C. Gordon, Robert W. Lytle, Johnnes K. Moore, Steven B. Olsen, Margalith Shalem, Marc S. Stuart, John H. Tietjen and Rochelle Wolkowski.

In 1960 Grøntved published an extensive work on the ^{14}C uptake of the sediment microflora of Danish fjords. In his procedure small cores of the sediment surface are separated to give a sediment fraction with adhering microflora and a fraction containing a suspension of the flora that is readily shaken free of the sediment. These fractions are exposed to ^{14}C in stoppered bottles that are placed on the bottom at the sediment site. The productivity is calculated from the radioactivity incorporated in these samples. Steemann Nielsen, who helped in the development of Grøntved's technique, has continued to use this method (personal communication), as have others following their lead. This method, and such refinements as presented by Hickman (1969) for separating epipelic and epipsammic algae, enable one to compare the productivity potential of the microflora of different sites; however, as Grøntved pointed out (personnal communication), such procedures do not indicate the natural rates of production in intact, undisturbed sediments.

Wetzel (1964) studied ^{14}C production rates by sediment microflora, without disrupting the sediment structure, by exposing periphyton under capped plexiglass cylinders placed over the bottom. In the method described herein small cores are removed intact from the sediment surface and exposed to ^{14}C in flasks that are immersed at the sampling site. Though there is some compaction involved in taking cores, the technique permits a scattered sampling over a sediment area in the time it would take to handle only a few of the cylinders (see discussion comments on our exploratory work with a technique similar to Wetzel's). Counting of the ^{14}C taken up by the microflora of these sediment cores is done by liquid scintillation spectrometry on suspensions of the sediment in Cab-O-Sil® gel. The productivity indicated by such methods is the primary photosynthesis of

organic matter by the microalgae, bacteria and other forms functioning in this capacity in the surface of the sediments.

Various workers have attempted to calculate benthic microflora productivity from the differences in oxygen in light and dark bottles or bell jars including or covering sediment samples. During the first year of our observations we ran oxygen bottles in series paralleling the ^{14}C uptake bottles. Extreme variability, coupled with our awareness that reducing and oxidizing reactions not directly related to primary synthesis and respiration may be taking place, led us to abandon further pursuit of such a technique.

A MATERIAL

10 - 250ml glass stoppered Erlenmeyer flasks, 6 uncovered and 4 covered with electrician's tape and aluminum foil

Rack designed to hold flasks on bottom during exposure at sampling site

Gelman type A, 47 mm glass fiber filters

Corers made from 12 cc disposable syringes (shown in Figure 1)

Polyethylene centrifuge caps to serve as core holders (shown in Figure 1)

Finger bowl

Long-handled, scissor-type forceps to lower caps into Erlenmyer flasks

Mortar and pestle

20 ml scintillation vials

Na H $^{14}CO_3$

Commercial formalin, neutralized

Cab-O-Sil from Godfrey Cabot, Inc.

PPO, (2,5-Diphenyloxazole)

POPOP, Dimethyl [1,4, bis- 2-(4-methyl-5-phenyloxazolyl)-benzine]

Toluene, analytical reagent grade

Equipment and accessories for measuring light, temperature, pH, salinity

Plus the various accessories for filtering, volumetric measurements, pipetting, recording, etc.

Access to liquid scintillation spectrometer

B FIELD PROCEDURES

Ten glass-stoppered 250 ml Erlenmeyer flasks, six uncovered and four completely covered with a first layer of electrician's tape and an outer layer of aluminum foil (the latter to offset heat absorption by the black tape) are used for holding small, intact core samples during exposure to ^{14}C. A volume of 97 ml of sea water, obtained from over the sampling site just prior to taking the cores and filtered through Gelman type A glass fiber filters, plus 3 ml of distilled water containing ca. 8 µc of Na H $^{14}CO_3$ are added to each flask. (In stenohaline areas, where a concern over dilution effect may arise, other combinations such as 99 ml water plus 1 ml ^{14}C may be used, assuming an equivalent µc level is provided. The activity of the added ^{14}C must be known as provided for in later steps.)

Samples to be placed in these flasks are collected with a corer machined from a 12 cc polyethylene syringe, Figure 1. Such corers can either be hand operated or manipulated with a holder such as is shown in Figure 2. Care is taken to obtain cores from undisturbed sediments. As the corer penetrates the sediment the plunger is above the drain holes. After penetration the plunger is lowered to cover these holes, making it possible to pull out intact cores from a wide range of mixed sand and mud bottoms. In handling, the corer with the contained sample is kept tilted upward to minimize disturbing the surface of the sediment sample.

Excess water is removed from over the core by supporting it from beneath with the finger tip and pressing down lightly on the plunger (if there is a large excess of water the sample is discarded). The plunger is then lowered until the lower portion of the core falls away and about 3/4 cm of the top of the core remains. A sample of this approximate depth has enough body to remain intact; presumably the activity to be measured is concentrated in the uppermost layers. Each core is then placed in a polyethylene cap (Figure 1) and held in a glass bowl of filtered s. w. until at least a dozen cores have been collected. As mentioned the compaction that takes place in collecting cores and transferring them to the container caps undoubtedly alters the sediment environment somewhat. When in the polyethylene cap and immersed in water, the cores can and, as judged by gross appearance, do expand again.

Once the samples have been collected ten good cores are selected and, with long-handled scissor forceps, six are lowered into the light flasks, four into the dark. The flasks, tightly stoppered, are placed in a weighted rack that is lowered onto the sediment surface at the site where the samples were collected. They are exposed to sunlight for 3 1/2 hours.

The temperature of the overlying water, needed for the productivity calculations, is taken at the beginning, mid-way and end during the exposure period. It is our practice to measure other field parameters of interest, particularly light, at these times. The pH and salinity of the filtered water introduced into the flasks are also determined. The pH is read 10 minutes after filtration, to avoid immediate effects of the vacuum involved in filtration, but no more than an hour after the water was collected. The salinity is determined by any standard method and whenever convenient.

At the end of the exposure period 1 ml of undiluted neutral formalin is added to each flask. As soon thereafter as possible and with a delay of no more than two hours, each flask is vigorously shaken to suspend the contained core and the suspension is transferred onto a Gelman type A glass fiber filter. Approximately 50 ml of additional s. w. is drawn through the filter to remove ^{14}C not incorporated by the microflora or otherwise tightly bound to the sample. (It is recognized that any delay between the weak formalin preservation, when the photosynthesis by the biota is stopped, and the time when the sample is transferred to a filter and washed may permit the release of unknown quantities of ^{14}C as a result of breakdown processes of the microflora cells. Since this is a field exposure taken back to the laboratory for filtering, the only feasible provision to minimize such errors is to keep delays to a minimum. The sea water wash will introduce an error, assumed to be minimal if any ^{14}C incorporated in the cells is lost in this step.)

The filters holding exposed sediment materials are stored until it is convenient to undertake the further steps. The assumption is that there is negligible loss from drying and storage, though Wallen and Geen, (1968) have found losses from phytoplankton during the drying process which suggest that it would be preferable to process filters while still wet if a satisfactory method could be found.

C SAMPLE PROCESSING AND COUNTING

The sample on the filter paper is placed in a wedgewood mortar and ground thoroughly using a pestle. The resulting powder is transferred quantitively to a vial where it is suspended in sufficient 4% Cab-O-Sil gel in toluene to bring the volume up to 30 ml. The suspension is shaken thoroughly, after which three 1 ml aliquots are pipetted into separate 20 ml scintillation vials containing 15 ml of 4% Cab-O-Sil gel and 1 ml of fluor concentrate

(PPO-8gm, POPOP-0.160 gm toluene-100 ml). The cap is screwed on and each vial is shaken vigorously.

The vials with the Cab-O-Sil gel suspension are placed into a liquid scintillation spectrometer and the ^{14}C activity determined. To evaluate the efficiency and correct for quenching an internal standard is added to each sample after the initial count and the sample and the standard are recounted. An external standard or a channels ratio method may also be used to calculate a correction factor for quenching.

To ascertain the activity of the ^{14}C added to the exposure flasks, vials are set up containing 15 ml of Bray's solution. To each vial 1 ml of Na $H^{14}CO_3$ is added in a concentration 1/30 the quantity added to each exposure flask. (See footnote 1 under D for an explanation of the concentration used.) The external standard method is used for quench and efficiency corrections. To evaluate different batches of Na $H\ ^{14}CO_3$ it is suggested that at least three solutions be prepared and that three scintillation vials be run on each.

D CALCULATION OF PRODUCTIVITY

The productivity of the sediment sample is determined using the following formula:

$$mgC/M^2/hr = \frac{1.05\ (R_L - R_D) \times W \times C}{R \times N}$$

R_L = light bottle d p m [1]

R_D = dark bottle d p m [1]

[1] Since aliquots are equal it is not necessary to convert to d p m per total volume.

W = weight of C in flask = $A \times F_T \times 12 \times 0.1$

A = carbonate alkalinity (derived as [2] Cl/L $_{(20)}$ x specific alkalinity of 0.123 and subtracting for non-carbonate alkalinity as given, for example, in Table VI.8 in Strickland and Parsons, 1968, Manual of Sea Water Analysis). In extreme brackish or freshwater it is necessary to measure alkalinity.

F_T = function of [2] pH, temperature and salinity. (Determined from Table VI.9 in Strickland and Parsons, 1968, Manual of Sea Water Analysis.)

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[2] pH, salinity and chlorinity are as determined on subsamples of the filtered water used in the flasks, with no correction for effect of adding the Na H CO_3 solution; temperature is asmeasured on the site during exposure.

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12 = Conversion for CO_2 from millequivalents CO_2/L to mgC/L

0.1 = converts from 1L to 100 ml

[1] R = d p m of ^{14}C added to exposure flasks

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[1] see footnote 1

N = hours of incubation (3.5)

C = number of cores in one square meter (16×10^3)

E PROCEDURE EVALUATIONS

Two limitations in the method have been noted above, namely the compaction and possible alteration of the sediment samples as they are cored and transferred to the caps that are used to hold them, and possible ^{14}C losses from the time of preservation in the field, the final rinse on the filters and through the drying process. Obviously the technique can only be used where sediments have sufficient cohesiveness to remain intact in the coring process. Also, the containment in the flask and consequent lack of flow over the sediment sample is not true to nature.

The selection of 3 1/2 hours as the period to expose the sediment samples to ^{14}C stems largely from the leads of other workers. Grøntved (1960) exposed for two hours in the middle of the day. Wetzel (1964) exposed from four to six hours. Though we never ran series that could be analyzed critically, we tried exposures over a range of three to six hours and found little difference. We have not dealt with some of the more involved questions to just what the ^{14}C uptake represents in the plant metabolism and, in relation to this, just what changes in uptake rate might take place with time.

The tables and discussion which follow not only evaluate the Cab-O-Sil suspension and counting method described herein but also compare this with our former methods involving wet oxidation and infrared combustion of the exposed sediment samples. The wet oxidation was accomplished by adding dichromate - sulfuric acid to a digestion flask and trapping the released CO_2 in NaOH. Bray's solution was added to an aliquot of this NaOH and scintillation counting done. The infrared combustion was conducted on 25mg aliquots of the dried and powdered core by the method of Davidson and Oliverio (1967). The trapped CO_2 was counted by liquid scintillation spectrometry. Prior to the current year wet oxidation had been our routine procedure for processing samples exposed at sites we are studying.

Table 1 presents the results of processing weighed aliquots of a simulated core suspended in Cab-O-Sil. The core was prepared by mixing ^{14}C labelled l-tryptamine of known activity, glass filter paper and sediment.

Later an exposed core was divided into approximate halves. One segment was wet oxidized, the $^{14}CO_2$ trapped in sodium hydroxide and aliquots counted in the liquid scintillation spectrometer. The remainder was in part processed in Cab-O-Sil suspensions. Also ten aliquots were processed by infrared combustion. The results, Table 2, indicate very favorable comparisons between the three methods. The Cab-O-Sil gel method is the fastest and simplest and replicate samples run (not possible in wet oxidation) show less variation than in the combustion method.

To extend the comparison with the wet oxidation method where replication within a single samples cannot be practiced, two series of cores were exposed to ^{14}C, as in the standard method described above, and divided. One half of each core was wet oxidized and the remainder used for Cab-O-Sil gel suspension and counting. Results are shown in Table 3 a and b. We cannot explain the contrast between the favorable comparisons of the first set and the discrepancies

Table 1 Assays of Cab-O-Sil suspensions of simulated cores

Wt. of sample mg	Theoretical activity dpm/mg	Activity found dpm/mg	Percent Recovery
31.1	144	142.9	99.2
28.0	144	152.8	106.1
25.5	144	133.9	92.9
26.4	144	139.8	97.0
25.5	144	134.2	93.1
24.0	144	129.6	90.0
24.2	144	145.7	101.1
28.2	144	131.8	91.5
27.8	144	148.4	103.0
26.6	144	129.4	89.8
		Mean	96.4
		Std. dev.	±5.8

Table 2. A comparison of wet oxidation, infrared combustion and Cab-O-Sil suspension methods applied to a single core.

Method	Activity found dpm/mg
Wet oxidation	15.9 (1 sample)
Infrared Combustion	14.9±2.3 (av. of 10)
Cab-O-Sil suspension	14.4±0.7 (av. of 10)

Table 3 A comparison of cores processed by the wet oxidation and Cab-O-Sil suspension methods.

a First set (Cab-O-Sil suspension readings are averages for 3 aliquots.)

Sample #	Wet oxidation Activity found dpm/mg	Cab-O-Sil suspension Activity found dpm/mg
1	28.7	29.9
2	15.8	17.3
3	27.4	26.1
4	13.6	19.9
5	28.3	27.1
6	17.5	17.2

b Second set (Cab-O-Sil suspension readings are averages for 5 aliquots.)

1	12.0	14.7
2	14.4	29.1
3	22.2	29.3
4	27.4	44.6
5	30.8	34.5
6	15.6	33.4
7	4.3*	4.2*
8	2.5*	3.1*
9	2.6*	1.7*
10	3.1*	3.8*

* dark bottles

in the second set. Since, once exposed, the samples can only lose, not gain radioactivity as they are processed, we must assume that the higher values obtained in the Cab-O-Sil processing are the more correct.

One of the requirements in using the Cab-O-Sil suspension method is to stay within an upper limit in the amount of suspended material counted. The need is demonstrated in Table 4. Judging from this and other experiments the total weight of sediment assayed should not greatly exceed 25 mg. All the Cab-O-Sil gel suspensions reported on in Table 1 - 3 were approximately of this weight.

To speed up processing, weighing out aliquots as done for the work presented in Table 1 - 4, was discontinued and the volumetric aliquot procedure presented in the methods section was adopted. The amounts involved in this procedure do not exceed 25 to 30 mg as recommended. This volumetric method has proven to be quite consistant. For example five 1 ml aliquots from one core gave readings of 12. 1 with a standard deviation of $\pm$ 0.3 dpm/mg, five from another gave readings of 19.7 with a standard deviation of $\pm$ 0.8.

If it were possible to utilize cellulose filters for collecting the sediment of exposed cores it would not be necessary to powder the cores and filter since, with vigorous agitation in a container with 4% Cab-O-Sil in toluene, the filter dissolves and only the sediment is suspended. Higher counting efficiency is obtained in this manner. Unfortunately glass fiber filters are required to reduce filtration time to a reasonable level. Attempts to disperse glass fibers by the above method resulted in lumpy gels which were difficult to pipette.

More important than any of the above procedural checks are the analyses of the reliability and sources of variance as this method is applied in the field. Such analyses are presented in the following section on results.

Table 4. The relationship between recovery of ^{14}C and weight of suspended material

Wt. of sample mg	Theoretical Activity dpm/mg	Activity Found cpm/mg	Percent Recovery
27.3	144	140.7	97.7
49.5	144	119.9	83.2
76.6	144	116.2	80.6
102.6	144	106.0	73/6

IV RESULTS

Exposed sediment samples show results obtained over an extended period (Table 5). Most of these were exposed over a mid-day 3 1/2 hour period. We also made observations to compare morning, mid-day and afternoon exposure and simultaneous exposure at three different depths.

In developing an estimate of the standard deviation of the productivity calculations, it is recognized that there is no pairing of light anddark bottles thus each light bottle and each dark bottle is regarded as a treatment level. Calculations of productivity are assumed to have been generated as a random sample of all possible combinations of 6 light and 4 dark bottle values for a particular site and date. The estimate on standard deviation is then based on a sample size of 24 (Table 5).

The variance as reflected in F ratios is associated with the light bottles (Table 6), exceptions occurring in the colder periods when production is low and the variability in dark bottles is comparatively greater. It is desirable, therefore, to ascertain whether the light bottle variation results from a technique flaw or from natural variability. Although triplicate data at the same stations and dates on chlorophyll a and phaeotype pigments have exhibited the same extreme variability encountered in light bottle data, further experimentation was considered necessary to ascertain whether such variability is natural. For this purpose on three of the sampling dates, plus one other date, additional sediment cores were taken with a plexiglass cylinder (3.8 cm diameter). Overlying water was drained off with a tube connector just above the sediment; the remaining water was pulled through from below using a hand pump, and an innoculum (100 ml) of 14C previously prepared in filtered seawater was added to the top. The system was closed and returned to the bottom. After exposure 30 core samples, of the size regularly processed, were withdrawn from the plexiglass cylinders, avoiding the initial compaction of the sediment which occurred in the regular procedure.

Table 5. Benthic microflora productivity as determined by 14C uptake at four different stations and analyzed by the Cab-O-Sil method. The n represents the number of possible light and dark bottle combinations; the s represents standard deviation.

Mystic				Middlebridge			
Date	$MgC/M^2/hr$	n	s	Date	$MgC/M^2/hr$	n	s
1/12/69	.002621	(20)	.003	1/19/69	9.9947	(24)	4.689
2/27/69	1.3817	(20)	2.235	3/1/69	5.3520	(24)	6.935
4/12/69	11.5442	(24)	8.523	5/4/69			
5/25/69	10.5381	(24)	9.226	morn.	48.3749	(24)	48.919
7/8/69	15.4785	(20)	13.832	noon	66.7164	(12)	34.823
8/25/69	4.8725	(24)	4.382	aft.	115.23	(20)	86.892
10/8/69	3.079	(24)	2.687	5/18/69			
				morn.	82.2662	(24)	29.605
				noon	109.3351	(24)	22.520
				aft.	164.9144	(16)	86.285
				5/30/69	23.0167	(24)	6.084
				7/10/69			
				morn.	41.7639	(20)	63.772
				noon	23.5377	(24)	17.276
				aft.	29.9000	(24)	20.069
				7/23/69			
				Deep	18.7526	(24)	24.921
				Mid	12.9607	(24)	15.105
				Shall.	13.4215	(24)	24.059
				8/28/69			
				Deep	27.6564	(24)	18.372
				Mid	31.3687	(24)	11.108
				Shall.	23.3380	(24)	22.600
				10/25/69	12.8916	(24)	21.381
				11/26/69	16.7336	(24)	31.406

Table 5. cont.

Pt. Judith				Millstone			
Date	$MgC/M^2/hr$	n	s	Date	$MgC/M^2/hr$	n	s
2/1/69	1.8597	(24)	4.458	2/15/69	1.1833	(20)	1.255
3/15/69	5.1277	(24)	6.203	3/29/69	4.0988	(16)	8.066
5/3/69	12.5515	(24)	30.442	5/10/69	16.5278	(16)	36.500
6/11/69	104.1998	(24)	108.467	6/24/69	16.4386	(24)	18.236
7/29/69	26.7640	(16)	11.661	8/8/69	3.4747	(24)	8.329
8/5/69				9/24/69	28.7540	(24)	29.115
Deep	31.2929	(18)	14.943	12/20/69	7.2877	(20)	7.049
Mid	35.5652	(20)	37.784				
Shall.	26.4725	(24)	20.100				
9/10/69	7.6878	(24)	7.181				
10/22/69	14.6694	(24)	22.966				
12/10/69	13.5490	(24)	6.925				

Table 6. F ratios determined by dividing the light and dark bottle mean squares by total variation from analyses of variance tests on 14C producitivity data from each sample date. No interaction between light and dark was observed.

Station	Date '69	Light Bottle	Dark Bottle
Mystic	1/12	3.18	2.12
Middlebridge	1/19	4.55	.05
Pt. Judith	2/1	3.18	2.36
Millstone	2/15	4.47	.42
Mystic	2/27	4.79	.02
Middlebridge	3/1	4.50	.01
Pt. Judith	3/15	4.55	.01
Millstone	3/29	4.76	.16
Pt. Judith	5/3	4.44	.07
Middlebridge	5/4		
	Morn.	4.68	.01
	Mid	2.16	.00
	Aft.	4.73	.00
Millstone	5/10	4.89	.08
Middlebridge	5/18		
	Morn.	4.68	.06
	Mid	4.36	.23
	Aft.	5.10	.00
Mystic	5/25	4.65	.01
Middlebridge	5/30	4.36	.35
Pt. Judith	6/11	4.54	.01
Millstone	6/24	4.53	.03
Mystic	7/28	4.75	.11
Middlebridge	7/10		
	Morn.	4.75	.03
	Mid	4.61	.07
	Aft.	3.50	1.94

Table 6. cont.

Station	Date '69	Light Bottle	Dark Bottle
Middlebridge	7/23		
	Deep,	4.58	.01
	Mid	4.49	.18
	Shall.	4.35	.19
Pt. Judith	7/29	3.47	.02
Pt. Judith	8/5		
	Deep	3.33	.10
	Mid	4.74	.00
	Shall.	4.63	.01
Millstone	8/8	4.34	.14
Mystic	8/25	4.16	.82
Middlebridge	8/28		
	Deep	4.15	.59
	Mid	4.55	.20
	Shall.	4.50	.26
Pt. Judith	9/19	4.50	.21
Millstone	9/24	4.64	.04
Mystic	10/8	4.06	.78
Pt. Judith	10/22	4.50	.00
Middlebridge	11/25	4.53	.04
Middlebridge	11/26	4.47	.01
Pt. Judith	12/10	4.36	.59
Millstone	12/20	4.67	.05

The results (Table 7) indicate a similar high variation between samples for both the plexiglass cylinders and for runs made by the usual method, but the three cores taken from the same cylinders were relatively uniform. Thus, it appears that variability will only be low when samples are taken adjacent to each other and that the variation encountered over short distances between samples is real and not a function of technique. While the variations encountered lead to very high standard deviations in many instances the fact that this is natural permits valid interpretation when enough field runs are available. We have, for example, been able to establish significant changes with seasons for given stations and have shown differences between field sampling stations within short periods of time.

Since no two workers have been dealing with comparable environments and using equivalent techniques, it is not possible to compare results critically. As noted Wetzel (1964) did work with intact bottom samples but he was dealing with periphyton on the gravel bottom of a freshwater lake. From ^{14}C uptake he observed an annual mean production of 731.5 mg C/M^2/day. Quite justifiably, in simulating conditions on a shifting sandy shore, Steele and Baird (1968) dispersed sediment samples over the bottom of exposure bottles, letting the particles shift and resettle much as they do in such an environment. The observed ^{14}C production rates ranged from 11-25 mg C/M^2/day, a low figure which one might expect for such a habitat. On numerous occassions we also dispersed sediments in exposure flasks, being interested in potential production that might be attained with the increased exposure of the microflora to light and to chemical exchange. Almost invariably the rates were higher than for intact sediments, sometimes by an order of magnitude. If they had shown any suggestion of pattern in relation to the intact cores, an effort would have been made to calculate a relationship and work with the easily-handled dispersed state.

Such comments call attention to the most extensive work of all, that of Grøntved (1960, 1962), particularly his most extensive work (1960) on the shoals of the Danish fjords which in gross respects are not unlike the es-

Table 7. Variation in 14C uptake of samples from the upper 3/4 cm of sediment in disintegrations per minute (dpm).

a) The standard sampling procedure.

Point Judith		Middlebridge		Middlebridge	
10/10/69		10/25/69		11/26/69	
light bottle	dark bottle	light bottle	dark bottle	light bottle	dark bottle
469	76	102	81	347	271
751	82	122	116	246	186
324	159	1252	175	2461	228
828	81	903	70	721	189
345		1590		2565	
749		1095		1611	

b) The plexiglass tube procedure.

Pt. Judith		Middlebridge		Middlebridge		Middlebridge	
10/10/69		10/25/69		11/19/69		11/26/69	
light tube	dark tube	light tube	dark tube	light tube	dark tube	light tube	dark tube
3419	179	[699	[181	[514	[109	[1224	[97
[2356 *	199	874		422		782	78
1626]		768]	170]	697]	119]	486]	104]
1600	128	[544	208]	[1551	83]	[1187	
2195	100	574		1014		699	
571		581]		1115]		1146]	
2459				[316			
				608			
				LOST]			

* figures in brackets are subsamples of a single tube sample

tuarine shoals sites. While Grøntved made it clear that his data on dispersed sediment microflora must be regarded as potential production figures, he did attempt a knowledgeable estimate of the actual production of the natural (undispersed) sediment, listing this as 318 mg C/M^2/day. Both Grøntved and Wetzel (1964) stressed that the benthic microflora production exceeded that of the phytoplankton community of the overlying water column. A production at least equal to if not in excess of phytoplankton rates also seems to characterize the estuarine shoals areas we have been studying.

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Figure 1. Corer constructed from a 12 cc polyethylene disposable syringe. Piston is 0.9 cm in diameter with a flattened head of clear Silicone Seal®, a General Electric product.

Also shown is a polyethylene centrifuge cap, about 1.1 cm in diameter, used as a core holder.

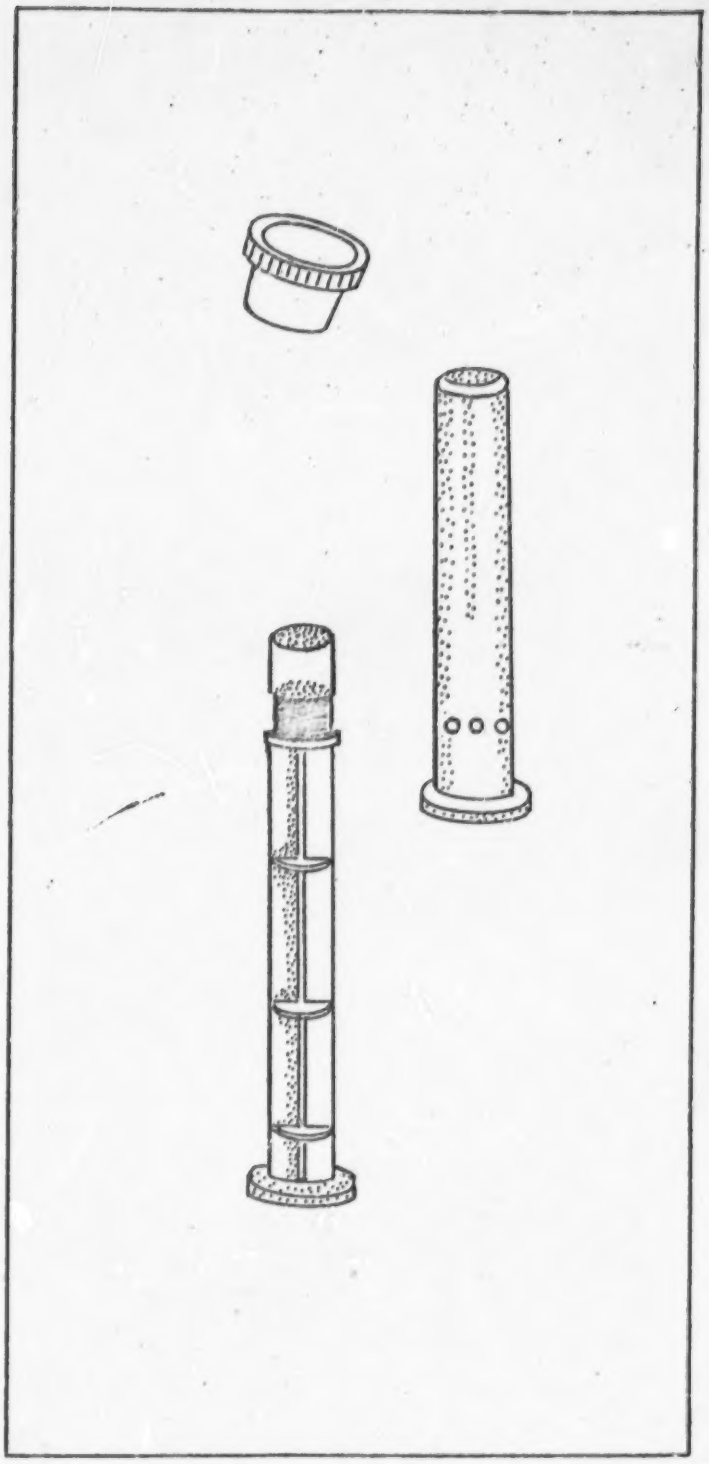
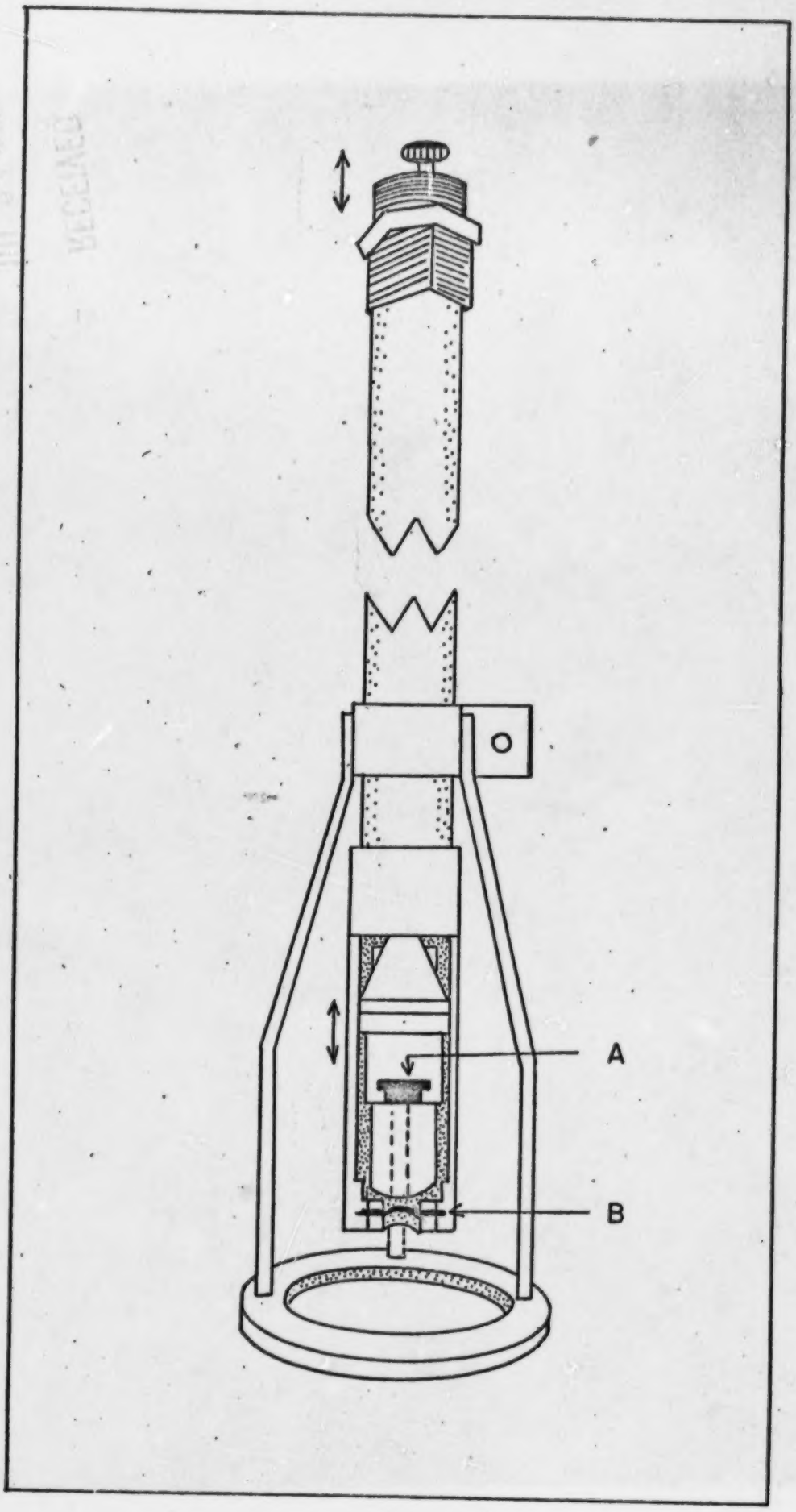


Figure 2. Holder for coring over the side of a skiff or in sites beyond reach by hand. A - slot for top of corer plunger, B - for collar of coring tube.



(50)

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This program was initiated in June 1967 to evaluate relationships between the productive condition of the sediment environment and pollution effects normally experienced along a densely populated coastline. Specifically the work was designed to:

(a) improve the methodology for measuring the productivity of the benthic microflora community;

(b) determine the normal rate of productivity of the microflora community of shoal benthic environments, as indicated by the rate of ^{14}C uptake by intact samples of samples; and

(c) compare this norm with productivity in an area affected by heavy domestic pollution and an area affected by thermal addition. (Limited results were obtained for this objective.) Data are presented on the reliability and variability of calculations of primary productivity.

Abstra

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